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6. AUTHOR(S)
Arthur Kaufman

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H Power Corp.
Belleville, NJ 07109

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H Power Corp. developed a fuel cell system to demonstrate that fuel cells can be effectively designed for missions requiring a high degree of compactness and light weight. This DARPA-funded, ARO-managed project resulted in a 40-watt, 90 watt-hour system contained within the confines of a case equivalent in size to that of a BA-5590 battery. The system comprised an air-cooled fuel cell stack, a metal-hydride-based fuel storage section, and a section that houses the system auxiliaries. Two units were constructed, tested, and delivered to ARO in 1996; these are periodically utilized for demonstration purposes within the Military.

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PEM FUEL CELL SYSTEM REPLACEMENT FOR BA-5590 BATTERY

BAA#94-46

Abstract

H Power Corp. developed a fuel cell system to demonstrate that fuel cells can be effectively designed for missions requiring a high degree of compactness and light weight. This DARPA-funded, ARO-managed project resulted in a 40-watt, 90 watt-hour system contained within the confines of a case equivalent in size to that of a BA-5590 battery. The system comprised an air-cooled fuel cell stack, a metal-hydride-based fuel storage section, and a section that houses the system auxiliaries. Two units were constructed, tested, and delivered to ARO in 1996; these are periodically utilized for demonstration purposes within the Military.

Introduction

The technical approach that was followed to address the objectives of this project entailed the following elements:

(i) Air-cooled fuel cell stack;
(ii) ambient-pressure stack operation and no external humidification so as to foster simplified operation and compactness;
(iii) 20-cell stack to obtain unregulated d.c. voltage within the desired 12-15 volt range;
(iv) graphite-based bipolar plates to take advantage of graphite's high thermal conductivity; fins on the long edges of plates to enhance heat transfer area;
(v) metal-hydride based hydrogen fuel storage;
(vi) system auxiliaries comprising a reactant-air blower (pump), a cooling fan, a hydrogen pressure regulator, a hydrogen outlet solenoid valve, a micropressor-based system controller and a start-up battery.

The load-profile to be addressed for BA-5590-type missions consisted of radio receiving and transmitting duty as follows:

Maximum (transmitting) load: 39 watts, 20% of the time
Minimum (receiving) load: 3 watts, 80% of the time

The durations of the transmitting and receiving periods were assumed to be 2 minutes and 8 minutes, respectively.

The BA-5590 case dimensions were 2.45 in. x 4.4 in. x 5 in.

Design and Development

The design of the fuel cell system provided for three separate sections that were stacked so as to arrive at a total system height within the BA-5590's 5.0 inch dimension. The fuel cell stack utilized 0.060 in. thick bipolar plates and a membrane-electrode assembly (MEA) thickness of about 0.025 in. The end-plates were 1/8 in. thick stainless steel. The resulting overall stack height was approximately 2.0 inches. The balance of the 5.0 in. dimension was divided equally between the metal-hydride canister and the auxiliaries section (1.5 in. for each).

The maximum utilization of space within the 2.45 in. X 4.4 in. dimension allowed a fuel cell active-area of approximately 28 cm2, after allotment of about 0.175 in. at each end of the smaller dimension for heat-rejection fins on the bipolar plates (and providing additional space for cell sealing). The design of the fuel cell stack's bipolar plate is depicted in Figure 1; a photograph of the overall system is shown in Figure 2.

The fuel cell stack output required at the peak power point was about 43 watts, taking the system auxiliaries' parasitic power demands into account. This power level was attained at a load of about 3 amperes and a cell voltage slightly in excess of 14V. This load was sustainable for periods of two minutes; for significantly longer periods the voltage would slump because of insufficiently robust cooling provisions, and the current would increase commensurately. Performance would recover in concert with a drop in stack temperature when the load was returned to the "receive" mode.

The metal-hydride canister was fabricated via welding of stainless steel sheet metal elements in prismatic form at a size of approximately 2.4 in. x 4.3 in. x 1.4 in. (outside dimensions). This unit fit snugly inside the sheet metal skin of the simulated BA-5590 battery case. An AB-5 type metal hydride (mischmetal) from Ergenics was used. These materials typically provide a net hydrogen capacity of about 1% by weight (allowing for unused hydrogen capacity at the low-pressure end of the discharge curve as well as for weight of inactive functional elements within the canister, but not for the weight of the canister structure per se). The energy capacity of this cartridge was about 90 watt-hours. It is anticipated that substantially higher energy capacity could be realized when the cartridge is utilized with an AB-2 type metal hydride; this material has a net hydrogen storage capacity that is about 50% higher than that of the AB-5 material.

Results and Discussion

The fuel cell stack, metal-hydride canister, and auxiliaries were fabricated and subjected to the appropriate test regimens. Trouble-shooting and fine-tuning were carried out as appropriate, and the respective components were then assembled into an integrated system. Considerable effort was required in the control system integration. Electronic functions required included:

(i) controlling the hydrogen outlet solenoid valve with a timer that opened the valve to allow for purging of the anode compartment for a fixed period of time (typically 1 second) and with a fixed interval (typically 2.5 minutes);

(ii) controlling the reactant-air delivery rate, as a function of load, by applying a pulse-width modulation (PWM) algorithm to the voltage imposed on the reactant-air pump;

(iii) controlling the fuel cell stack's temperature by starting/stopping the cooling fan in response to a signal from the stack's temperature sensor;

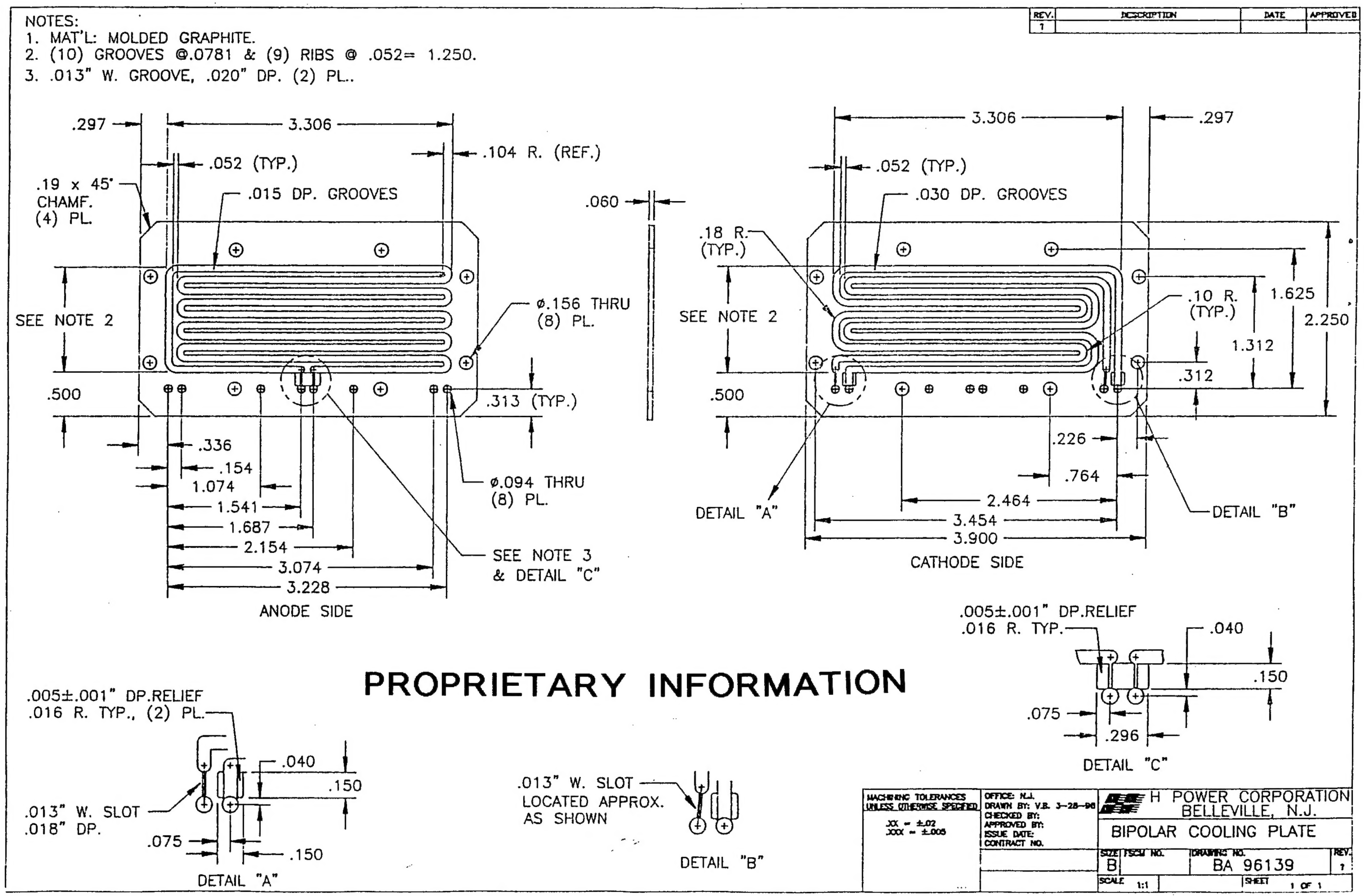
(iv) controlling the fuel cell system's start-up, shutdown, and emergency-action regimens; utilizing power from the start-up battery where necessary to allow functions such as reactant-air pump starting and hydrogen-purge solenoid valve opening.

The system was operated under steady-state conditions over a range of loads, and it was found to operate in accordance with the design objectives. As expected, at high load levels (greater than about two-thirds of peak load) the system could not operate stably for a sustained period of time (although the two-minute peak-load period could be handled adequately). As discussed earlier, more rugged cooling provisions would be required to allow such operation.

An electronically-controlled load was used to simulate the load-profile that is taken to be characteristic of the radio transmit/receive duty cycle (see above). The system was found to follow the profile very adequately, and the sequence could be sustained indefinitely in this manner.

Recommendations

It is recommended that the effort to develop compact, lightweight PEM fuel cell power sources be continued to take advantage of the encouraging results discussed herein. Military applications that could take advantage of the relatively high energy-density of fuel cell systems should be identified. Advanced fuel cell development should be directed toward higher power-density in fuel cell stacks, higher hydrogen-storage energy-density, and improved system auxiliary components.

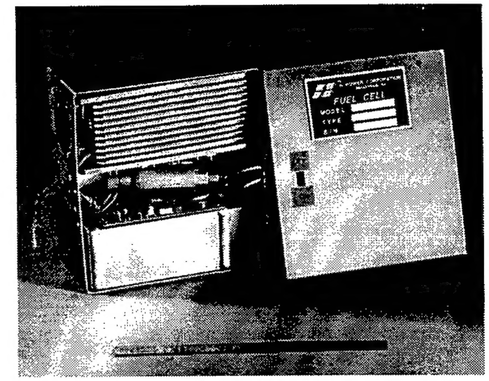


NOTES:
1. MAT'L: MOLDED GRAPHITE.
2. (10) GROOVES @.0781 & (9) RIBS @ .052= 1.250.
3. .013" W. GROOVE, .020" DP. (2) PL..
REV.
DESCRIPTION
DATE
APPROVED
1
.297
3.306
.052 (TYP.)
.104 R. (REF.)
.19 x 45° CHAMF. (4) PL.
.015 DP. GROOVES
SEE NOTE 2
ø.156 THRU (8) PL.
.500
.313 (TYP.)
.336
.154
1.074
1.541
1.687
2.154
3.074
3.228
ø.094 THRU (8) PL.
SEE NOTE 3 & DETAIL "C"
ANODE SIDE
.060
.030 DP. GROOVES
.18 R. (TYP.)
.10 R. (TYP.)
1.625
2.250
1.312
.312
.226
.764
2.464
3.454
3.900
DETAIL "A"
DETAIL "B"
CATHODE SIDE
PROPRIETARY INFORMATION
.005±.001" DP.RELIEF
.016 R. TYP., (2) PL.
.013" W. SLOT
.018" DP.
.040
.150
.075
DETAIL "A"
.013" W. SLOT LOCATED APPROX. AS SHOWN
DETAIL "B"
.005±.001" DP.RELIEF
.016 R. TYP.
.040
.150
.075
.296
DETAIL "C"
MACHINING TOLERANCES UNLESS OTHERWISE SPECIFIED
.XX = ±.02
.XXX = ±.005
OFFICE: N.J.
DRAWN BY: V.B. 3-28-96
CHECKED BY:
APPROVED BY:
ISSUE DATE:
CONTRACT NO.
H POWER CORPORATION
BELLEVILLE, N.J.
BIPOLAR COOLING PLATE
SIZE B
FSCM NO.
DRAWING NO. BA 96139
REV. 1
SCALE 1:1
SHEET 1 OF 1

FIGURE 1

Small Fuel Cell Systems
• BA-5590FCI •

FIGURE 2



- **Net Power Output:**
  - 10W nominal
  - 40W peak
- **Voltage:**
  - 12V nominal
- **Fuel Cell Stack Type:**
  - BA
- **Fuel:**
  - Metal hydride canister (rechargeable)
- **Applications:**
  - Misc.. military
- **Energy Storage :**
  - 90Whr
- **Status:**
  - Engineering-prototypes fabricated, tested, and shipped for demonstration use

H POWER